Visual Restoration Using Keratoprosthesis Surgery

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The term ocular surface refers to a complex unit that is comprised by many structures acting in an integrated and coordinated fashion to achieve comfort and excellent vision for the patient. A healthy tear film is vital for a healthy ocular surface. They provide lubrication, nutrition, trophic health factors, mechanical drainage conduits to remove trapped debris, and contain antimicrobial defense systems. A healthy lid and blink mechanism helps to facilitate the proper spread of tears and also in maintaining the drainage dynamics. Diseases that interfere with these factors will result in damage to the ocular structures as well.

The physical ocular surface is constituted by the conjunctival and corneal epithelial compartments and their distinctness is supported and maintained by the presence of a healthy limbus. Since many diseases can affect one or more or sometimes all of these structures, the commonest example being chemical burns of the ocular surface, the reconstruction of these damaged eyes is a complex process and requires attention to the many alterations that are present. In eyes with end-stage disease, resulting in a skin-like appearance of the ocular surface with extensive disorganization of the lid-eye relationships, a keratoprosthesis offers hope of visual rehabilitation.

If normal tear function is subnormal the use of newer tear substitutes that are either unpreserved or contain preservatives that are less toxic to the surface, tear preservation using punctual plugs or surgical options, and restoring tear secretion by transfer of the parotid duct or transplantation of the submandibular salivary gland may be needed. The use of secretagogues like oral pilocarpine has shown some promise in early trials, despite the presence of significant side effects.

Cicatrization of the conjunctiva can result in tethering of the lids to the globe and restriction of movement of both the lids and the globe. The principles of surgery include the thorough release of all adhesions of the conjunctiva to the globe and excision of the fibrotic scar tissues, restoring the normal anatomy in the region. In order to prevent a recurrence of the condition, it is important that sufficient regenerative potential is present in the conjunctival tissues. In this context, it is important during surgery to use a substrate that will serve to separate the raw tissues of the globe and the lids and will also promote conjunctival epithelial healing, while at the same time reducing the scarring response of the ocular tissues. The ideal material that provides these functions is amniotic membrane. If however, it appears that the extensive conjunctival loss has resulted in little potential for regeneration, it may be important to use a conjunctival substitute to reconstruct the surface. Traditionally, oral mucosa has been used and provides acceptable results, despite the anatomical differences compared to the normal conjunctiva.

In the context of corneal surface reconstruction, one of the important problems that often confront a surgeon...
A. Stage I

The affected eye

Osteodental lamina – cylinder complex implanted in subcutaneous pocket

The extracted tooth

Pannus removal from affected eye

Osteodental lamina prepared from tooth

Excised cheek mucosal flap

PMMA cylinder glued to osteodental lamina

Mucosa sutured to ocular surface
B. Stage II

- Osteodental lamina – cylinder complex removed from pocket
- Mucosal flap retracted from ocular surface
- Central cornea trephined
- Iris removed completely
- Cryoextraction of lens
- Limited anterior vitrectomy
- Lamina implanted in eye
- Lamina covered by mucosal flap with central opening for cylinder
is the presence of a persistent epithelial defect (PED). By definition this is a corneal ulcer that has persisted for 2 weeks despite adequate therapy. Such a persistent breach in the corneal epithelium has the potential to progress, often rapidly, to serious complications such as corneal infection, vascularization, thinning and even perforation. For the purpose of this discussion it is assumed that the persistent ulcer is not due to corneal infection – as the treatment approach of this entity is beyond the scope of this article. If an infection has been ruled out, it may then be necessary to identify the actual cause of the PED to allow a systematic approach to the diagnosis and management. The concept of the XYZ hypothesis is useful in addressing this problem.

The XYZ hypothesis proposed by Richard Thoft postulates that the health of the corneal epithelial surface is maintained if the relationship $X + Y = Z$ is present. The term $X$ refers to the centripetal migration of epithelial cells from the limbus into the corneal epithelial pool, while $Y$ represents the upward epithelial migration from the basal layers of the epithelium. The combination of these two should match the factor $Z$ which represents loss form the surface. Any imbalance in this relationship can affect the health and integrity of the corneal epithelial surface.

If the problem is with the factor $X$ – meaning that adequate corneal epithelial cells are not being produced by the limbus, it is necessary to pay attention to restoring the limbal stem cell population in these eyes. On the other hand the problem may be with the factor $Y$ – the cells produced at the limbus may have difficulty in migrating across the corneal surface, in adhering to the underlying structures, and therefore unable to further multiply and provide the upward growth phase. If this is identified as a factor, then efforts to resolve the underlying issues can be undertaken. Depending on the underlying condition, one or more of the following options may be considered -

- Pressure patching / contact lens
- Diluted topical steroids
- Debridement / Superficial keratectomy
- Corneal glue
- Anterior stromal puncture
- Amniotic membrane patch graft

The use of autoserum tears, proposed by Tsubota, can be an useful adjunct in this situation. The rationale for their use is that the serum is likely to contain many of the trophic factors that are present in normal tears and the use of these factors as topical drops can help healing in such eyes.

Thus, ocular surface problems have many manifestations and causes and careful attention must be paid to the examination of such eyes, in order to determine the causative factors. A planned, often staged surgical approach must then be considered to ensure that these factors are tackled appropriately. When such an approach is followed, adequate restoration of ocular surface function is possible in most instances. However, in a subset of eyes with end-stage disease, where the surface appears keratinized, the hostile surface environment and total lack of an ocular surface defense, results in very poor survival of any transplanted biological tissues. In such eyes, the only hope for restoration of visual function is the use of prosthetic devices and the use of the modified osteo-odontokeratoprosthesis (MOOKP) is described. This technique uses a composite bone-tooth lamina to help anchor a polymethyl methacrylate cylinder to the cornea. Originally pioneered by Prof Strampelli, it has evolved to its present form due to the interest and expertise of Prof Giancarlo Falcinelli from Italy.
The complex surgical procedure is performed in two stages. In the first stage, a canine tooth is harvested from the mouth of the patient after X-ray screening has determined that the tooth has a healthy and viable root structure. A surgical motorized saw is used to excise the canine root encased in alveolar bone from the jaw. The lamina is fashioned by sawing through the root of the tooth in a longitudinal fashion to expose the dentine and the root canal. The pulp in the root canal is scraped off and a hole is drilled in the widest part of the root – to a size of 3 to 4 mm depending on the width of the root at that point. An appropriate sized plastic cylinder of appropriate power (determined from the axial length of the eye to be operated) is then glued to the hole using dental cement. A subcutaneous pocket is created in the tissues of the cheek and the lamina-cylinder complex is placed and the pocket is sutured closed after installing antibiotic powder. In the eye, the symblephara are released, and scar tissue is excised as described earlier. A superficial keratectomy including the Bowman’s layer is performed to expose the bare corneal stroma after which a full-thickness circular piece of cheek mucosa about 4 mm in diameter is placed over the cornea and sutured to sclera, also covering the muscle insertions.

Stage II is performed 2 to 3 months later to allow time for a connective tissue cover to develop around the lamina implanted in the cheek. If required the integrity of the lamina can be checked by performing a spiral computed tomographic evaluation. During the second stage surgery, the lamina is retrieved from the subcutaneous location and excess connective tissue is removed from the two ends of the optic cylinder, and trimmed over the rest of the lamina. The mucosal graft on the ocular surface is incised superiorly and reflected from the superior sclera and cornea, in a downward direction. The inferior attachment of the mucosal graft is left undisturbed to ensure that the blood supply is retained.

A Flieringa ring is sutured in place and a 3mm opening is created in the center of the cornea. Three radial incisions are made in the cornea extending till the limbus. The iris is torn at the root and removed and hypotensive anesthesia is used to control the ooze. Constant irrigation with balanced salt solution also helps wash the blood away and prevents a large clot from forming in the anterior chamber. The lens is then cryoextracted and the corneal radial cuts are sutured closed. A limited anterior vitrectomy is performed and the lamina is then placed over the cornea, such that the posterior part of the optic cylinder is in the anterior chamber – entering through the central corneal opening. The lamina is sutured into position using the connective tissue covering and episcleral bites. At the conclusion of suturing, indirect ophthalmoscopy is performed to ensure that there is a good view of the disc and posterior pole. If this is not seen, a cylinder tilt may be responsible and sutures need to be adjusted to straighten the cylinder. Any bleeding into the vitreous cavity can also interfere with the visualization. After the cylinder and lamina are in satisfactory position, the mucosal flap is replaced and a small opening is created over the optic cylinder to allow the anterior portion of the cylinder to protrude through the mucosa. The superior edge of the mucosal flap is sutured in place and this completes the operation.